FINAL STATUS SURVEY PLAN

Li Tungsten Site
683 Herb Hill Road
Glen Cove, New York 11542

CERCLIS ID: NYD986882660
NYS Site Code: 130046

FSSP (Rev. A)
June 2014

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ABBREVIATIONS, ACRONYMS, AND SYMBOLS

bgs	below ground surface
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
cm	centimeter
CoC	Chain of Custody
cpm	counts per minute
DCGL	Derived Concentration Guideline Level
DQO	Data Quality Objective
EMC	Elevated Measurement Comparison
EPA	US Environmental Protection Agency
ESD	Explanation of Significant Differences
FSS	Final Status Survey
FSSP	Final Status Survey Plan
ft	foot/feet
GWS	Gamma Walkover Survey
HSA	Historical Site Assessment
LBGR	Lower-Bound Gray Region
m	meter
m^2	meter squared
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDC	Minimum Detectable Concentration
MDCR	Minimum Detectable Count Rate
$MDCR_S$	Minimum Detectable Count Rate-Surveyor
NaI	Sodium Iodide
NIST	National Institute of Standards and Technology
No.	Number
NPL	National Priorities List
NY	New York
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
pCi	picoCuries
PESI	Perma-Fix Environmental Services, Inc.
PWG	P.W. Grosser, Inc.
QA	Quality Assurance
QAP	Quality Assurance Program

QAPP	Quality Assurance Project Plan
QC	Quality Control
Ra-226	Radium-226
Ra-228	Radium-228
RCOC	Radiological Contaminant of Concern
ROD	Record of Decision
Th-230	Thorium-230
Th-232	Thorium-232
US	United States
WRS	Wilcoxon Rank Sum

1.0 INTRODUCTION

Perma-Fix Environmental Services, Inc. (PESI) has been selected to conduct Final Status Survey (FSS) at the historic Li Tungsten Superfund Site (Site) located at 683 Herb Hill Road Glen Cove, New York (NY); roughly 25 miles east-northeast of New York City (**Figure 1-1**). The Site is identified on the *National Priorities List* (NPL) as “Li Tungsten Corp.” with the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) identification number NYD986882660. The Site is also listed as a Class 2 Inactive Hazardous Waste Site, identified as “Li Tungsten” within the NY State Superfund Program, with Site Code number 130046.

The Site has gone through several investigations and remedial efforts dating back to 1988. A *Record of Decision* (ROD) (EPA, 1999) was issued in 1999 that presented the cleanup criteria that were applied during subsequent remedial efforts in 2001 and 2003. In 2005, an *Explanation of Significant Differences* (ESD) (EPA, 2005) was issued that revised the 1999 criteria to the currently accepted cleanup criteria on the Site (Refer to Section 2.2). According to the U.S. Environmental Protection Agency (EPA), the site currently satisfies the ESD criteria. However, in 2013, the NY State Department of Environmental Conservation (NYSDEC) and Department of Health (NYSDOH) identified potential radiological data gaps that require attention and resolution prior to NYS releasing the Site for development. This Final Status Survey Plan (FSSP) presents the design and implementation guidelines for resolving valid data gap concerns and for demonstrating that the data-gap areas of the Site satisfy the 2005 ESD criteria.

Historically, the site has been divided into three main parcels (**Figure 1-2**).

- Parcel A is approximately 7 acres in size and is bounded by Glen Cove Creek to the south, Herb Hill Road to the north, Dickson Street and Doxey to the West, and the Gateway Properties to the east. This parcel housed operating and processing facilities for the Li Tungsten Corporation. Parcel A was remediated and verified as clean against the 2005 ESD radiological criteria by the EPA as documented in the 2008 *Remedial Action Report for Operable Unit One (Li Tungsten Facility)* (EPA, 2008). Parcel A represents a data gap concern for NYSDEC due to the inability of EPA to produce the data or reports that were the basis for the conclusions stated in the 2005 ESD Additionally, the footprint of the recently demolished Lounge Building was identified by the developer as a potential data gap.

- Parcel B is approximately 6 acres in size and is located to the north of Parcel A, with Herb Hill Road forming its southern boundary. Other bounds of Parcel B include Dickson Street to the west, ‘The Place” Street to the north, and Crown Dykman to the east. Parcel B was a primarily undeveloped land area that was used for parking and some waste disposal operations. Following remediation, Parcel B was subject to an FSS in accordance with MARSSIM (EPA, 2000), and was verified as radiologically clean as documented in the *Post-Remedial Actions at parcel B and Upper parcel C Li Tungsten Superfund Site, Glen Cove, New York* (TDY, 2009). Parcel B does not contain data gaps and the MARSSIM data support its radiologically-clean status; therefore, no further FSS activities on Parcel B are necessary.

- Parcel C is approximately 10 acres in size and is typically divided into two contiguous sections that are identified as Lower Parcel C and Upper Parcel C (Parcel C-Prime does not present a radiological hazard and is excluded from this FSSP). Parcel C is bordered by Dickson Street to the east (across from Parcel B), Garvies Point Road to the south, residential properties to the north, and undeveloped properties to the west. Parcel C was historically used for water treatment as well as some waste disposal operations.

    - Upper Parcel C was subject to an FSS in accordance with MARSSIM (EPA, 2000), and was verified as radiologically clean as documented in the *Post-Remedial Actions at parcel B and Upper parcel C Li Tungsten Superfund Site, Glen Cove, New York* (TDY, 2009). However, the footprints of the recently demolished Benbow Building and Dickson Warehouse represent potential data gaps that will be addressed in this FSSP. It should be noted that a sub-slab investigation was performed beneath Dickson Warehouse in 2014.

    - Lower Parcel C was remediated and verified as clean against the 2005 ESD radiological criteria by the EPA as documented in the 2008 *Remedial Action Report for Operable Unit One (Li Tungsten Facility)* (EPA, 2008). Lower Parcel C represents a data gap concern for NYSDEC due to the inability of EPA to produce the data or reports that were the basis for the conclusions stated in the 2005 ESD.

Radionuclide Contaminants of concern (RCOCs) on the Site include Radium-226 (Ra-226), Radium-228 (Ra-228), Thorium-230 (Th-230), and Thorium-232 (Th-232). This FSSP includes a means to statistically evaluate soil contamination levels for residual RCOCs by using the MARSSIM process. This process includes a historical site assessment, the establishment of data quality objectives, release criteria, FSS design, data evaluation, and the method for making conclusions as to the status of the site relative to the release criteria. The primary objective of this data collection effort is to, in a timely manner, effectively demonstrate the radiological status of the Site relative to the 2005 ESD criteria (EPA, 2005).

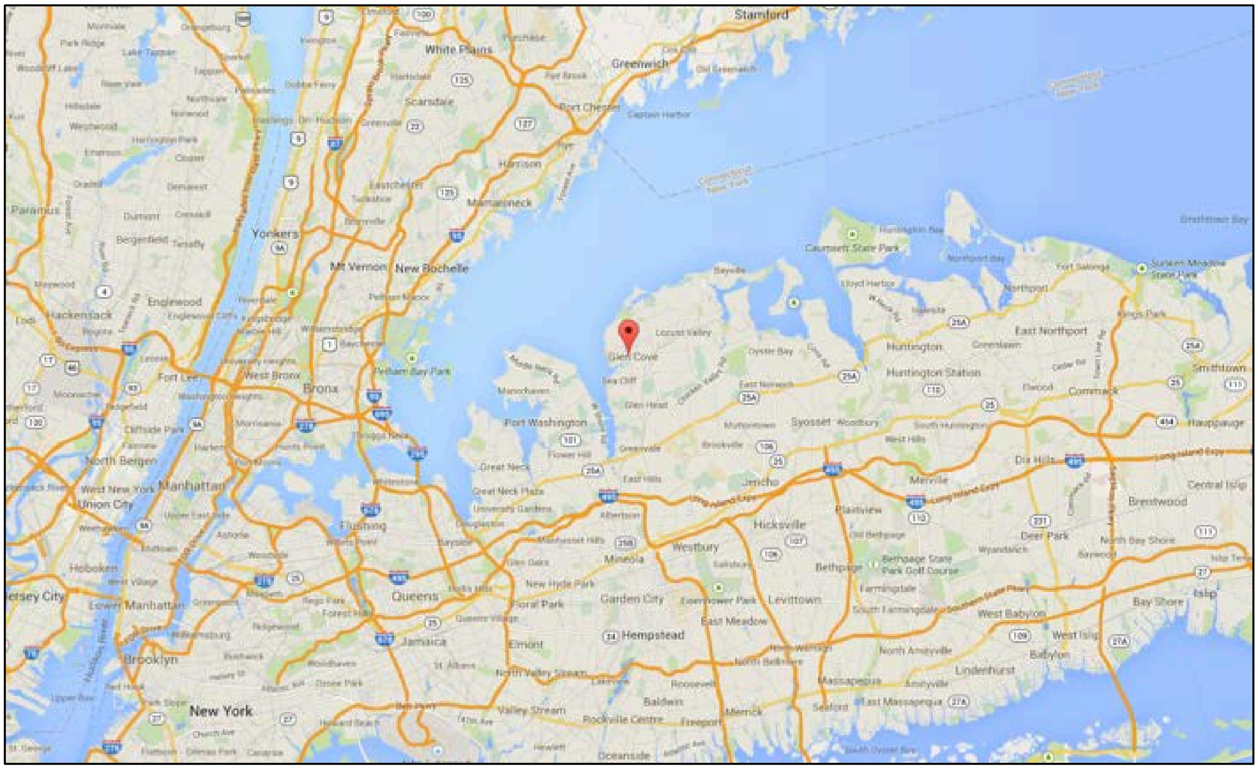

Figure 1-1: Li Tungsten Site Location

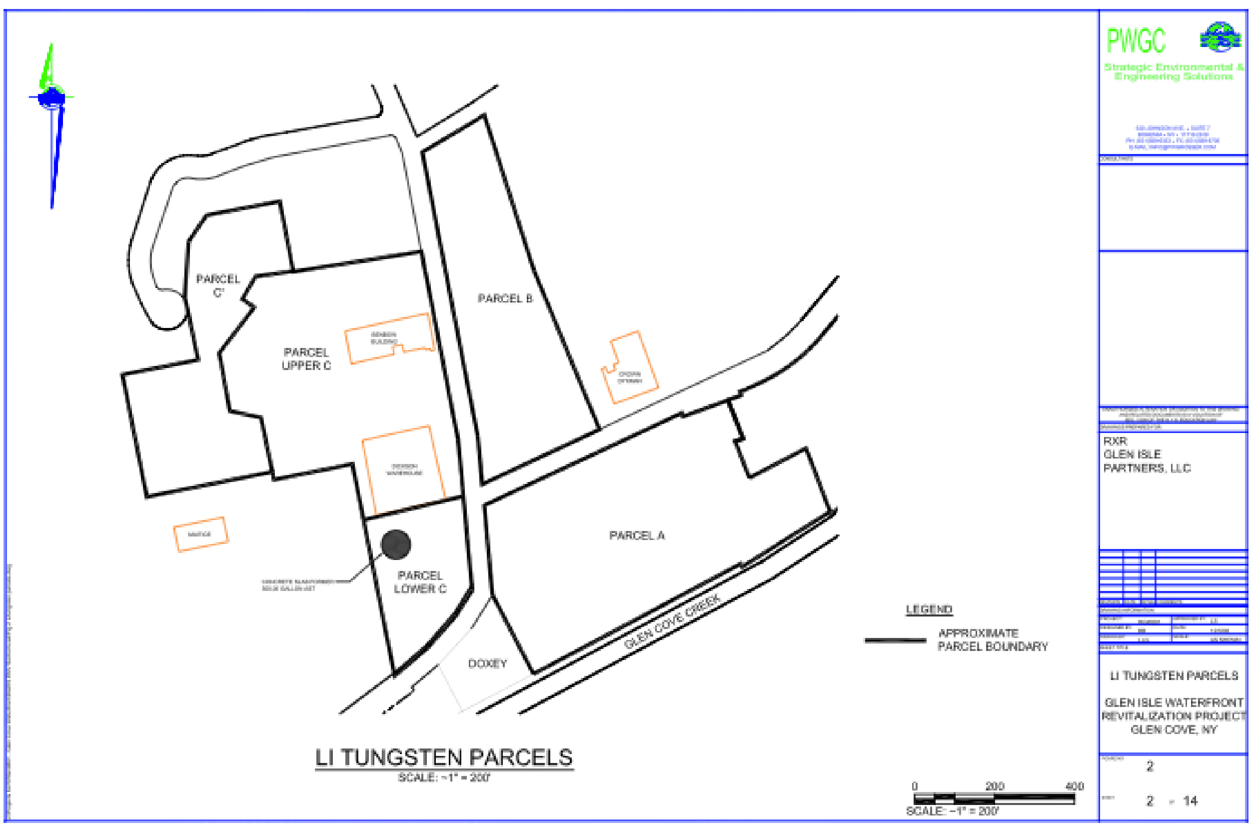

Figure 1-2: Li Tungsten Parcels

2.0 PRELIMINARY CONSIDERATIONS

2.1 Historical Site Assessment

A robust historical site assessment (HSA) was performed leading up to the development of this FSSP as documented in the *Li Tungsten Data Gap Review and Response to DEC/DOH Comments and Recommendations for Parcels A, B, and C, and Captains Cove* (PESI, 2014a), and the *Justification for Class 2 Survey Units on Parcel A and Lower Parcel C at Li Tungsten, Site No. 130046* (PESI, 2014b). Pertinent findings are summarized here:

- Fred C. Hart and Associates performed site-wide gamma scan surveys as a first step in site characterization as far back as 1988. The actual gamma readings were not available for review, but various documents (see PESI, 2014a) indicate that the results of these gamma surveys were used to delineate remediation areas on Parcel A and Lower Parcel C.
- In accordance with the 1999 ROD (EPA, 1999), Parcel A and Lower Parcel C were remediated by the EPA in 2001. During final verification, all but three areas were successfully remediated to meet 1999 ROD criteria based on composite sample results. These three “exempt” areas were addressed during a subsequent remedial effort in 2003 and all three areas were successfully remediated to meet 1999 ROD criteria based on composite sample results.
- Also in 2003, a comprehensive surface and subsurface investigation was performed in all Parcels and no radiological exceedances were identified (Metron, 2004).
- In 2005, the ESD modified the release criteria as presented in the 1999 ROD. EPA reviewed all the existing data against the new criteria and determined that the new criteria were satisfied (EPA, 2008).
- A MARSSIM FSS was performed on Parcel B and Upper Parcel C between 2006 and 2007, which demonstrated that both excavated and unexcavated areas of these parcel’s satisfied the 2005 ESD criteria (TDY, 2009).
- In 2014, another comprehensive surface and subsurface investigation was performed that again identified no radiological exceedances (PWG, 2014).

Despite all the indications that Parcel A and Lower Parcel C meet the 2005 ESD criteria, there is not enough data available currently to perform an evaluation in accordance with MARSSIM. Therefore, it was recommended that Parcel A and Lower Parcel C undergo a MARSSIM FSS (PESI, 2014a).

Parcel B and Upper Parcel C have undergone fully-compliant MARSSIMs surveys and have statistically significant data to support a release decision. Therefore, no further FSS is recommended for Parcel B and Upper Parcel C, with the exception of the footprints of recently demolished buildings located on Upper Parcel C.

2.2 Cleanup Criteria

The applicable cleanup criteria for the Site were established in the 2005 ESD (EPA, 2005). The 2005 criteria modified the 1999 ROD criteria (EPA, 1999) by including an additional radium isotope (Ra-228) and an additional thorium isotope (Th-230) to the original Ra-226 and Th-232 RCOCs. The 2005 ESD criteria consist of the following:

- Ra-226 combined with Ra-228: Less than 5 pCi/g above background.
- Th-230 combined with Th-232: Less than 5 pCi/g above background.

These are the cleanup criteria that will be applied during the data evaluation phase of the FSSP. Comparisons of FSS data sets to these criteria will be used to support release decisions.

Note that there is no requirement for comparing the overall combination of the different elements (i.e., no "Sum-of-Ratio" requirement; rather, radium will be evaluated independently of thorium).

2.3 Background Activity

A background dataset has previously been approved for use at the Site. This background dataset was established for the Parcel B and Upper Parcel C Final Status Surveys that were conducted between April 2006 and August 2007. Details of the background dataset were summarized in the 2009 Final Status Survey Report:

> "*A background reference area is a geographical area from which representative samples of background conditions are selected for comparison with samples collected in specific survey units at the remediated site (NUREG-1505). The Project Health Physicist (HP) collected 11 background reference samples from a location with no indication of residual radioactive contamination and representative of the background radiological conditions for the geographic region. Background reference samples were obtained from a wooded and park-like area at 200 Dosoris Lane, Glen Cove, New York. The background sample results are presented as **Table 5-13*** [see **Table 2-1** of this FSSP] *and the sample values are also used in each Wilcoxon Rank Sum (WRS) Statistical Test.*"
>
> \- *Final Final Status Survey Report* (TDY, 2009)

This background data set contains 11 sample points, which is sufficient – based on this FSSP design – for use with the anticipated number of systematic sample locations (10) within each FSS survey unit (refer to **Section 4.2**).

The Background reference data set, along with pertinent statistics, is provided in **Table 2-1**. This data set serves two primary purposes:

1. To establish levels of regional background to be used for background subtraction when comparing sample results to the cleanup criteria.
2. To provide data points for use with the WRS Test when evaluating survey unit data.

In the event that more background data is needed, additional reference area data may be collected to augment this data set. Additionally, Data may be collected to establish background gross gamma readings for surface and/or down-hole gamma logging as appropriate.

Table 2-1: Background Reference Area Data

Sample Number	Ra-226 Result (pCi/g)	Ra-228 Result (pCi/g)	Ra-226 + Ra-228 (pCi/g)	Th-230 Result (pCi/g)	Th-232 Result (pCi/g)	Th-230 + Th-232 (pCi/g)
5601-BKGD-1001	0.68	1.32	2	0.79	0.73	1.52
5601-BKGD-1002	1.1	0.99	2.09	0.65	0.72	1.37
5601-BKGD-1003	0.8	1.07	1.87	0.59	0.62	1.21
5601-BKGD-1004	1.16	0.95	2.11	0.64	0.84	1.48
5601-BKGD-1005	0.94	0.77	1.71	0.55	0.68	1.23
5601-BKGD-1006	0.97	0.73	1.7	0.52	0.6	1.12
5601-BKGD-1007	0.93	0.68	1.61	0.47	0.7	1.17
5601-BKGD-1008	1.18	0.8	1.98	0.83	0.72	1.55
5601-BKGD-1009	0.94	0.86	1.8	0.5	0.75	1.25
5601-BKGD-1010	1.09	0.73	1.82	0.42	0.72	1.14
5601-BKGD-1011	1.01	0.58	1.59	0.43	0.54	0.97
Average	0.98	0.86	1.84	0.58	0.69	1.27
Standard Deviation	0.15	0.21	0.18	0.14	0.08	0.18
95% Confidence Level	1.28	1.28	2.21	0.85	0.86	1.64

Note: Table reproduced from *Final Status Survey Report* (TDY, 2009)

2.4 Characterization Data

Characterization data for the Site was reviewed during the HSA and included several sources of information that gave a broad scope of radiological conditions in both the surface and subsurface. These sources of information were summarized in the *Li Tungsten Data Gap Review and Response to DEC/DOH Comments and Recommendations for Parcels A, B, and C, and Captains Cove* (PESI, 2014a), and the *Justification for Class 2 Survey Units on Parcel A and Lower Parcel C at Li Tungsten, Site No. 130046* (PESI, 2014b). These documents are available for review online at https://www.dropbox.com/sh/jspccbmhlrmgw2o/ffYEgtKTi4. In general, the information indicates that no surveyed areas of the Site contain above-criteria RCOCs concentrations. However, the recent 2014 investigation provides the best analytical data, and was therefore used for the purposes of designing MARSSIM surveys in accordance with this FSSP.

During the 2014 investigation, 28 samples were analyzed via alpha spectrometry and gamma spectrometry. These samples were collected from locations throughout the site and complete analytical data is provided in **Attachment 1**. **Table 2-2** provides a summary of the radium and thorium data pertinent to this FSSP. This data was used as a means to estimate the anticipated variability of the of the FSS data sets. Variability (sigma, σ) is a key parameter of interest for designing MARSSIM surveys; the variability of the characterization data is used to estimate the minimum sampling requirements for each FSS survey unit.

Table 2-2: 2014 Analytical Data Summary

Sample ID	Radium-226 + Radium-228	Thorium-230 + Thorium-232
LT-C-013	2.021	1.564
LT-C-066	2.226	1.338
LT-G-029	2.858	1.573
LT-XC-020	1.452	0.796
LT-C-018	1.818	1.425
LT-C-067	0.986	0.701
LT-G-029	2.858	1.573
LT-XC-020	1.452	0.796
LT-C-045	1.51	0.75
LT-X-002	1.462	1.371
LT-R-001	2.422	1.026
LT-XC-021	0.619	0.47
LT-C-048	1.254	0.583
LT-G-019	1.098	0.473
LT-R-001	2.861	1.429
LT-XC-023	1.312	0.768
LT-C-049	1.608	0.864
LT-G-026	1.304	0.756
LT-R-002	1.735	0.86
LT-C-060	1.056	0.667
LT-G-027	2.413	0.738
LT-R-002	1.629	1.345
LT-C-064	1.386	0.78
LT-G-028	4.0	1.758
LT-R-003	1.374	1.193
LT-C-065	1.669	1.066
LT-G-029	3.62	1.734
LT-R-003	1.452	1.099
Average	1.791	1.019
STDEV	0.883	0.388
Min	0.619	0.470
Max	4.000	1.758

3.0 DATA QUALITY OBJECTIVES

Data Quality Objectives (DQOs) are qualitative and quantitative statements that establish a systematic procedure for defining the criteria by which data collection design is satisfied in order to support release decisions for a survey unit. The DQOs at the Site include:

- Clarifying the problem;
- Defining the data necessary for achieving the end use decisions;
- Determining the appropriate method of data collection; and
- Specifying the level of decision errors acceptable for establishing the quantity and quality of data needed to support the project decisions.

The overall Quality Assurance (QA) objective for this FSSP is to develop and implement a methodology for obtaining and evaluating data that meet the DQOs to evaluate whether the cleanup criteria are satisfied. Specifically, radionuclide data will be generated to demonstrate that the Site has achieved the remediation criteria. QA procedures are established to ensure that field measurements, sampling methods, and analytical data provide information that is comparable and representative of actual field conditions, and that the data generated are technically defensible.

To determine DQOs, a series of planning steps are used, as specified in the U.S. Environmental Protection Agency (EPA) Guidance for Data Quality Objective Process QA/G-4 (EPA, 2006), to identify the data needed to support project decisions and develop a data collection methodology. The process is intended to be iterative, optimizing data collection to meet the applicable decision criteria.

3.1 State the Problem

The Site has been extensively investigated, remediated, and evaluated via FSS; however, data gaps exist due to: (1) the inability of EPA to produce the data or reports that were the basis for the conclusions stated in the 2005 ESD, and (2) inaccessible regions underneath buildings that were still standing at the time of previous surveys; these buildings have subsequently been demolished thereby making the ground surface within each building footprint accessible.

RCOCs at the Site have been identified as Ra-226 + Ra-228, and Th-230 + Th-232. The currently accepted cleanup criteria, as promulgated in the 2005 ESD (EPA, 2005), and as stated in **Section 2.2** of this FSSP, is 5.0 pCi/g above background for each nuclide pair.

The “problem” therefore is to demonstrate that the identified data gap areas satisfy, or dissatisfy, the cleanup criteria for the RCOCs. Therefore, the goal of this FSSP is to design a survey methodology, in accordance with MARSSIM, which will demonstrate with a level of confidence, the residual activity of RCOCs relative to the 2005 cleanup criteria.

3.2 Identify the Decision

The surveys will be designed to provide adequate data for making statistically defensible decisions regarding the release status of the Site. If the survey data indicates that the Site satisfies cleanup criteria then no further action is required relative to radiological contamination. If the data indicates that the residual contamination exceeds cleanup criteria, then additional evaluations, investigation, and/or remediation may be required.

3.3 Identify Inputs to the Decision

Decisions will be based on the data received from a combination of surveying and sampling events, including, but not limited to, field surveys and analytical laboratory results. The objective of the survey and sampling activities are to identify the concentrations of residual radioactive material in the survey units. This information will allow determination of whether or not a survey unit is likely to be suitable for release. The average soil concentrations will be evaluated to verify that the radiological cleanup criteria are met. Compliance will be demonstrated using:

- Systematic Soil Samples
- Biased Soil Samples
- Gamma Walkover Surveys
- Gamma Down-hole Surveys, if applicable
- Data Evaluation

3.4 Define the Study Boundaries

Data Population:
The data population of interest for the Site is the concentration of RCOCs and their associated comparison to the release criteria. A separate data population of concern is the activity concentration of RCOCs in the designated background reference area.

Spatial and Temporal Boundaries:
Survey units will subdivide the information geographically. The spatial boundaries of the project are horizontally limited to land areas located in the Site boundaries of Parcel A (including the Lounge Building footprint), Lower Parcel C, and footprints/work areas of the Dickson warehouse and Benbow building on Upper Parcel C. The vertical study area primarily includes surface soil over the vast majority of the Site. In pre-identified “exempt” areas, subsurface investigation may be performed to depths corresponding to historical limits of excavation. The study period begins with acceptance of this document and runs throughout the duration of FSS activities, culminating in the acceptance of Final Status Survey Reports by stakeholders.

Constraints on Data Collection:
Appropriate constraints will be placed on data collection to ensure high quality data is collected. All samples will be taken in accordance with the methodology identified in this FSSP, as well as applicable PESI procedures including a site-specific Field Sampling Plan.

3.5 Develop a Decision Rule

Parameter of Interest:
Parameters of interest are the mean, median, and standard deviation of data collected during the study. Nonparametric statistical tests will be utilized to determine whether or not the level of residual activity uniformly distributed throughout the survey unit exceeds the cleanup criteria. Since these methods are based on ranks, the results are generally expressed in terms of the

median. In some cases, the mean may exceed the median. For this reason, the arithmetic mean of the survey unit data will also be compared to the cleanup criteria as a first step in the interpretation of the data. By using a graded approach to data testing as discussed below, decisions will be made according to the decision rule stated at the end of this discussion.

Scale of Decision Making:
Decisions are made on two fundamental scales: the survey unit, and smaller localized areas of elevated activity. Localized areas of elevated radiation levels are evaluated on an ongoing basis throughout the field effort. In cases where clear indications of elevated measurements are observed, decisions on remediation, survey unit subdivision, etc., may be made as appropriate. On a larger scale, and as a final determination, data will be evaluated on a survey-unit specific basis. For localized areas with radioactive concentrations above the cleanup criteria, an elevated measurement comparison (EMC) will be performed.

Action Level:
Decisions on a survey unit's acceptability are based on a comparison of the measured residual radioactivity concentrations in survey units and the background, subject to applicable statistical analyses specified in MARSSIM. The action level corresponds to the established cleanup criteria.

Decision Inputs:
Scanning and analytical results (gamma spectroscopy) will be used to evaluate the effectiveness of remedial activities. Results will be compared to soil cleanup criteria discussed in **Section 2.2**. Determination of whether or not RCOC concentrations exceed background concentrations by more than the cleanup criteria will be made using all collected data and a strict statistical methodology. If the survey unit does not meet the cleanup criteria, further investigation is warranted. This application of decision rules or investigation levels may prompt collection of additional samples, further remediation, or reclassification of the survey unit. If the survey unit meets the cleanup criteria, no further remediation will be required.

Decision Rule:

1. Compare the survey unit data directly to the cleanup criteria:
    a. If all individual systematic and bias samples results are below the cleanup criteria, after background subtraction, then the survey unit passes and no further evaluation is necessary.
    b. If any single measurement is above cleanup criteria, after background subtraction, then further evaluation needed; proceed to Step 2.
2. Perform the statistical tests:
    a. Perform the WRS Test:
        i. If any systematic sample results are above the cleanup criteria, after background subtraction, then perform the WRS Test as detailed in **Section 4.4**. Passing the WRS Test is a strong indication that the survey unit may pass.
    b. Perform the EMC Test:
        i. If any sample result (systematic or bias) is above the cleanup criteria, after background subtraction, then perform the EMC test as detailed in **Section 4.4**. Passing the EMC Test is a strong indication that the survey unit may pass.

3. Perform a retrospective sample frequency evaluation:
   a. A retrospective sample frequency evaluation looks at the known variability of the systematic data set (as opposed to the *a priori* variability generated from the characterization data) to determine if enough samples were collected to provide sufficient statistical strength.

Note that the retrospective sample frequency evaluation is only used as an indication of confidence in the outcome(s) of the tests performed in Steps 1 and 2. If it is determined that a sufficient number of samples were collected then confidence in the outcome is high. However, in no way does a determination that an insufficient number of samples were collected indicate that a survey unit fails; in this case, professional judgment is required to evaluate all available data and determine a proper course of action.

3.6 Define Acceptable Limits on Decision Errors

The decisions necessary to determine compliance with the soil cleanup criteria are based on precise statistical statements called hypotheses. These hypotheses will be tested using data from a survey unit. The state that is presumed to exist is expressed as the null hypothesis (H_0). For a given Null Hypothesis, there is a specified Alternative Hypothesis (H_a) that is an expression of what is believed to be the state of reality if the null hypothesis is not true.

Null and Alternative Hypotheses:
The hypotheses selected for the FSS are as follows:

<u>Null Hypothesis</u> (H_0):
The median concentration in the survey unit exceeds the median concentration in the reference area by more than the cleanup criteria.

Versus:

<u>Alternative Hypothesis</u> (H_a):
The median concentration in the survey unit does not exceed the median concentration in the reference area by more than the cleanup criteria.

These hypotheses were chosen because the burden of proof is on the Null Hypothesis. Therefore, the survey unit will not be released until proven to meet the cleanup criteria. The measured median concentration in the survey unit must be less than the cleanup criteria in order to pass.

These hypotheses also were chosen because contamination below the cleanup criteria is measurable. Releasing a survey unit that requires additional remediation is an unacceptable alternative.

Statistically based decisions will be utilized for evaluating the release criteria. Statistical acceptability decisions, however, are always subject to error. Two possible error types are associated with such decisions. These are discussed below and summarized in **Table 3-1**.

Table 3-1: Hypothesis Testing and Consequences of Errors

		Survey Unit Decision	
	Hypothesis	*"Success"* (Reject H_O)	*"Failure"* (Accept H_O)
"True" Condition of the Survey Unit	**H_A** Meets remedial objective (e.g., at or below cleanup criterion)	No decision error (probability = 1 - α)	Incorrectly fail to release survey unit (Type II error with probability = β)
	H_O Exceeds remedial objective (e.g., exceeds cleanup criterion)	Incorrectly release survey unit (Type I error with probability = α)	No decision error (probability = 1 - β)

The first type of decision error, called a Type I error, occurs when the null hypothesis (H_o) is rejected when it is actually true. A Type I error is sometimes called a 'false positive'. The probability of a Type I error is usually called "alpha" and is denoted by α. This error could result in higher potential doses to future site occupants than prescribed by the cleanup criterion. Therefore, for the purposes of this study, the maximum Type I error rate will be set to 0.05. This is considered acceptable due to the reasonably anticipated future land-use of the Property.

The second type of decision error, called a Type II error, occurs when the null hypothesis is not rejected when it is actually false. A Type II error is sometimes called a 'false negative'. The probability of a Type II error is usually called "beta" and is denoted by β. The power of a statistical test is defined as the probability of rejecting the null hypothesis when it is false. It is numerically equal to 1-β. Consequences of Type II errors include unnecessary remediation expense and project delays. For the purposes of this study, the maximum Type II error rate will be β=0.05.

Relative Shift:
The lower boundary of the gray region (LBGR) and the target values for α and β are selected during the DQO process. For FSS planning purposes at the Site, and in accordance with MARSSIM, the LBGR is set to one-half the cleanup criteria. The width of the gray region (DCGL - LBGR), is a parameter that is central to the Wilcoxon Rank Sum (WRS) test. This parameter also is referred to as the shift, Δ. The absolute size of the shift is actually of less importance than the relative shift Δ/σ, where σ is an estimate of the standard deviation of the measured values in the survey unit. For planning purposes, the estimate of σ was based on the Characterization Data (see **Section 2.4**). For data evaluation purposes, the actual σ of the systematic data set is applied. The relative shift, Δ/σ, is an expression of the resolution of the measurements in terms of measurement uncertainty. The value of the relative shift is used to calculate the number of samples required to demonstrate that a survey unit has met the applicable release criteria.

3.7 Optimizing the Design

The variability of data will have an effect on the sampling design. If necessary, the sample frequency and the analytical procedures will undergo changes to optimize the design. Changes will occur concurrently for several steps within the DQO process. The design options, such as sample collection design, sample size, and analytical procedures will be evaluated based on cost and the ability to meet the DQOs. The number of measurement and sample locations are addressed in **Section 4.0**. This FSS design follows the framework for design outlined in Sections 4 and 5 of MARSSIM (EPA, 2000).

4.0 FINAL STATUS SURVEY DESIGN

This section provides a detailed overview of the additional design components, which are based on those established in **Section 2.0** (HSA, background reference activity, estimated data variability – sigma, and cleanup criteria) and in **Section 3.0** (DQOs including hypothesis testing and acceptable error rates). Additional components include:

- Survey unit classification (based on the HSA)
- Numbers and locations of discrete samples (based on characterization σ)
- Gamma scanning parameters
- Data evaluation techniques including:
    - Interpretation of survey results
    - Wilcoxon-Rank Sum evaluation (WRS Test)
    - Elevated measurement comparison test (EMC Test)
    - Retrospective statistical strength evaluation.

4.1 Survey Unit Classification

Prior investigations, remedial efforts, FSSs, and a recent HSA have been performed on the Site and have been used as the basis for the initial determination of the area classifications established in this section. The historic Site data and the HSA were used to determine the current radiological status of the Site. Area classification decisions are made relative to the cleanup criteria as follows:

- **Class 1** areas are known or expected to have radionuclide concentrations above the cleanup criteria.
- **Class 2** areas are known or expected to have radionuclide concentrations above normal background concentrations but that are not expected to be above the cleanup criteria.
- **Class 3** areas are not expected to contain any residual radioactivity, or only contain levels that are a small fraction of the cleanup criteria.

As relates to pertinent areas of the Site addressed in this FSSP (Parcel A, Lower Parcel C, and building footprints), all areas were appropriately classified as “Class 2” in accordance with the above MARSSIM definitions and the *Class 2 Justification Memorandum* (PESI, 2014b).

The recommended conditions for demonstrating compliance based on a Class 2 survey unit designation (MARSSIM Table 2.2) includes: systematic sampling (discrete samples), performing gamma scans over 10- to 100- percent of the survey unit, statistical testing (WRS Test), and EMC evaluations. These parameters are discussed in greater detail through the remainder of this Section.

4.1.1 Reassignment of Survey Unit Classification

The initial area classifications are based on a combination of available data and historical information. Additional information obtained during the implementation of the FSSP may lead to the determination that the initial classifications established in **Section 4.1** should be revised to be consistent with the definitions (also given in **Section 4.1**). Each survey area classification change will be recorded as an FSSP variation and will be documented and may require approval by stakeholders prior to implementation.

In general, any area classification may be upgraded to a more restrictive final survey protocol (e.g., from Class 2 to Class 1) upon receipt of additional survey or measurement information that justifies the need for the higher classification. Stakeholders will be notified and contractual agreements will be made prior to upgrading survey unit classification.

Downgrading an area classification to a less restrictive final survey protocol (e.g., from Class 2 to Class 3) is not expected, but would require regulatory approval prior to implementation.

4.1.2 Survey Unit Size

MARSSIM recommends the maximum size for a Class 2 survey unit be limited to 10,000 square meters (m^2). This FSSP intends to conform to this recommendation. However, in cases where logistical considerations and/or survey results indicate a need to modify the design, and where those modifications would otherwise result in a small orphaned area, additional area may be added to an existing survey unit provided that the original systematic grid spacing (see Section 4.2) is maintained and extended into the additional area. This translates to collecting more samples within that survey unit, commensurate with the amount of additional area. It is not anticipated that exceeding the recommended survey unit size will occur during implementation of the FSSP.

4.2 Number of Samples per Survey Unit

The number of samples required for the WRS test is ultimately driven by the variability of the data set, the residual concentration of RCOCs relative to the cleanup criteria, and the acceptable decision error rates. The evaluation is made specific to each cleanup criterion and the most restrictive sampling requirement is applied. **Table 4-1** summarizes the *a priori* evaluation used to determine the number of samples required per survey unit. After data is collected and evaluated, a retrospective evaluation is performed to confirm that sufficient measurements were collected to support release decisions.

Table 4-1: Sample Location Requirements per Survey Unit

Sample Location (N/2) Requirement Evaluation	Class 2 Survey Units	
	Ra-226 + Ra-228	Th-230 + Th-232
Parameter	**Value**	**Value**
Cleanup Criteria:	5.0 pCi/g	5.0 pCi/g
Lower Bound of Gray Region (LBGR): *a priori* value equal to 1/2 cleanup criteria	2.5 pCi/g	2.5 pCi/g
Shift Δ: (Cleanup Criteria – LBGR)	2.5 pCi/g	2.5 pCi/g
Estimated Standard Deviation σ: (σ from 2014 Investigation – 28 data points)	0.87 pCi/g	0.43 pCi/g
Relative Shift (Δ/σ):	2.84	6.44
Probability Function Pr: (From MARSSIM Table 5.1, using the relative shift above)	0.974067	1.000000
Estimated Minimum Number of Discrete Sample Locations (N/2): (Using MARSSIM Table 5.3, alpha and beta = 0.05)	10	9

Based on the N/2 evaluation presented in **Table 4-1**, a minimum of 10 samples will be collected from each Class 2 survey unit as driven by the Ra-226 + Ra-228 criterion. Note that this minimum requirement includes an additional 20 percent to account for potentially lost or unusable data in accordance MARSSIM.

4.2.1 Locating Discrete Samples

The results of discrete soil sampling will be used to verify that the soil concentrations are less than the acceptance criteria. A predetermined minimum number of samples will be collected in each survey unit based on the evaluation presented in **Table 4-1**. A random-start triangular pattern, or grid (generally the most efficient means of identifying small areas of elevated activity as opposed to a square grid), will be used in each survey unit to locate the soil samples. The triangular grid has approximately a 90 percent chance of detecting a circular hot spot of radius equal to one-half the grid spacing. The spacing of this systematic grid would be:

$$L = \sqrt{\frac{A}{0.866(N)}} \tag{1}$$

Where:

L = triangular grid spacing for survey unit (m)
A = area of survey unit (m^2)
N = number of sample locations

For a 10,000 m^2 survey unit that consisted of 10 sample locations, *L* would be equal to 33.98 meters. This value of *L* would actually remain constant for all survey units greater than 10,000 m^2 (larger survey units are not anticipated during implementation of the FSSP). For survey units less than 10,000 m^2, the grid spacing will be reduced to meet the *a priori* minimum sampling requirement of 10 sample locations.

The routine method of random sampling described above presumes that the actual scan MDC is less than or equal to the required scan MDC, i.e., that there is sufficient scan sensitivity available to detect small areas of elevated activity. Based on a review of historical site data, the established cleanup criteria and the *a priori* scan-MDC evaluation (see **Section 4.3**), gamma scans can be used effectively at the Site to identify areas that require further investigation. For areas that require additional investigation, discrete bias samples may also be collected in addition to the systematic samples.

The systematic grid will be randomly distributed for each survey unit. The random start point (X and Y coordinates) will be selected using a readily available random number generator such as the "RAND()" function in the Microsoft computer application Excel© (or the Visual Sample Plan computer application), or the methodology outlined in Section 5.5.2.5 of MARSSIM. Sample points will be identified in the field by flags or other means using a global positioning system (or equivalent locating tool) to spot each grid node. Beginning at the random starting point, a row of measurement locations or points is identified parallel to the X axis at intervals of L. For a triangular grid, a second row of points is then developed parallel to the first row, and off-set at a distance of 0.866 x L from the first row. To ensure a sufficient number of data points are obtained for statistical purposes, the value of L should be rounded down to the nearest whole meter (m) that can be easily measured in the field. If a point falls outside the survey unit or at locations that cannot be surveyed, additional points may be determined using a random selection process. **Table 4-2** presents examples of grid spacing for various survey unit sizes. The size of the "Hot Spot" reflects that area that may be missed by the random sampling grid, these areas are addressed through scanning (see **Section 4.3**).

Table 4-2: Example FSS Land Area Sample Collection Density

Area *A* (m^2)	No. of Samples (*N*)	Distance between Grid Nodes *L* (m)	Size of "Hot Spot" (m^2)
5,000	10	24.03	453.52
7,500	10	29.43	680.25
8,000	10	30.39	725.36
9,000	10	32.24	816.36
10,000 +	10	33.98	906.85

To ensure a sufficient number of data points are obtained for statistical purposes, the value of L is rounded down to the nearest whole meter which is easily measured in the field. If a point falls outside the survey unit or at locations that cannot be surveyed, additional points may be determined using a random selection process. Survey unit-specific grid spacing will be calculated for each survey unit after actual sizes are determined from field surveys.

4.2.2 Bias Samples

A bias sample is a sample, either surface or subsurface, whose location has been intentionally selected to target areas of concern based on either the results of the gamma surveys or due to historical areas of concern identified during the HSA.

Initially, based on regulator comments and the preliminary HSA results, there were six (6) areas that were identified as potential subsurface investigation areas. However, during subsequent HSA activities, it was determined that the areas of concern were either fully remediated in 2001, or were subsequently remediated in 2003 to meet the 2005 ESD criteria (PESI, 2014b).

During the course of FSS activities, based on gamma scan results and/or stakeholder direction, surface and/or subsurface bias samples may be collected. Bias samples results will be compared directly to the cleanup criteria to establish compliance (i.e., they are not evaluated using the WRS test). Elevated bias sample results may be subject to EMC testing, in which case additional samples may be collected to bound the area of elevated activity and to assign area factors in accordance with MARSSIM (see **Section 4.4**).

Bias areas identified by either gamma scanning or by historical areas of concern will be adequately investigated to ensure that the activity and extent of the areas are known.

4.3 Gamma Walkover Surveys

Gamma Walkover Survey (GWS) scans are performed to identify isolated areas of elevated radioactivity that may not be detected by discrete soil sampling (i.e., confirm that radiological conditions in each survey unit are reasonably uniform). GWS scans of the soil surfaces within survey units are performed using a Differential Global Positioning System (DGPS) coupled to a Ludlum Model 44-10 2-inch by 2-inch sodium iodide (2x2 NaI) detector with a Ludlum Model 2221 scaler/ratemeter. The GWS will be performed following a MARSSIM protocol by scanning straight lines at a rate of approximately 0.5 meters per second while moving the detector in a serpentine motion of approximately one meter wide and a consistent distance from the soil surfaces. GWS data in gross counts per minute (cpm) from the ratemeter/scaler will automatically be logged into the DGPS handheld unit at a rate of once per second.

4.3.1 Minimum Land Area Scan Coverage

MARSSIM recommends that the minimum land area scan coverage for a Class 2 survey unit be between 10 and 100 percent. For the purposes of this FSS design, GWS will to the extent possible, be performed over 100 percent of all accessible areas within each survey unit. This is equivalent to the scan coverage requirement for a Class 1 survey and is considered appropriate for this FSS effort.

4.3.2 Scan Minimum Detectable Concentration

Scan Minimum Detectable Concentration (Scan-MDC, or MDC_{scan}) is a parameter of central importance to a MARSSIM survey. The ability to effectively detect small, localized areas of elevated activity that may be missed during the collection of random systematic sample locations is necessary to ensure that all areas of a survey unit are adequately investigated and allows for greater confidence in the outcome of the statistical tests.

Field instrument use will be evaluated and controlled to verify that MDCs less than the appropriate limit for scanning measurements are routinely achieved. Implementation of these MDC requirements is discussed below. The MARSSIM framework for determining the MDC for field instrument scanning activities is based on the premise that there are two stages of scanning. That is, surveyors do not make decisions on the basis of a single indication; rather, upon noting an increased number of counts, they pause briefly and then decide whether to move on or take further measurements. Thus, scanning consists of two components: continuous monitoring and stationary sampling. Accordingly, field instrument surveyor scan MDCs, minimum detectable count rate-surveyor ($MDCR_S$), are calculated to control the occurrence of Type I (false positive) and Type II (false negative) errors using the following MARSSIM equation:

$$MDCR_S = \frac{MDCR}{\sqrt{p\varepsilon}} \tag{2}$$

Where MDCR is the minimum detectable count rate [counts per minute (cpm)], p is the surveyor efficiency (estimated in MARSSIM to be between 0.5 and 0.75; the value of 0.5 results in a more conservative $MDCR_S$ calculation and, therefore, will be used), and ε is the instrument efficiency (cpm per μR/hr; Table 6.4, NRC 1998). In addition:

$$MDCR = s_i\left(\frac{60}{i}\right) \tag{3}$$

Where:

$$s_i = d'\sqrt{b_i} \tag{4}$$

Where s_i (counts) is the minimal number of net source counts required for a specified level of performance for the counting interval i (seconds); d' is the index of sensitivity; and b_i is the number of background counts in the interval. Index of sensitivity d' values are listed in MARSSIM Table 6.5 based on the proportions for required true positive and tolerable false positive occurrence rates. The index of sensitivity value selected for initial use at the Site is 1.38, corresponding to a true positive proportion of 0.95 and a false positive proportion of 0.60. While this index of sensitivity value will result in at least 95 percent “correct” scanning detections as required by the Site DQO for Type I error control, up to 60 percent “incorrect” (false positive) scanning detections may occur. For the purpose of this survey, the high rate of false positives is considered appropriate to ensure that an adequate investigation is performed. However, should this become an intolerable compromise, a larger index of sensitivity value corresponding to the 0.95 true positive proportion may instead be used provided the required scan MDC is achieved.

Calculated scan MDCs for a survey instrument equipped with 2x2 NaI scintillation detector using the MARSSIM two-stage scanning framework are summarized for a 15 cm thick contamination layer of Ra-226 and Th-232 in **Table 4-3** below.

Table 4-3: 2x2 NaI Scintillation Dector Scan-MDCs

Radionuclide	Scan MDC (pCi/g)[a]	Single Radionuclide Cleanup Criteria (pCi/g)[b]
Ra-226[c]	2.0	2.5
Th-232[c]	1.3	2.5

[a] Background level assumed to be 5,000 cpm (conservative based on recent survey data).
[b] Set to one-half the combination of Ra-226+Ra-228 and Th-230+Th-232, respectively.
[c] In equilibrium with progeny.

As shown in **Table 4-3**, the Scan-MDC for Ra-226 and Th-232 are comfortably below their respective DCGL values. Scan-MDCs using a 2x2 NaI detector and the scanning technique described above are expected to be significantly lower. Additionally, the absence of strong gamma emissions from Ra-228 and Th-230 is accounted for by reducing the "Single Radionuclide Cleanup Criteria" by one-half of the combined cleanup criteria (5.0 pCi/g).

4.4 Interpretation of Survey Results

The initial evaluation of survey results will determine compliance for each survey unit by comparing survey unit statistics (mean, and/or median, and maximum) against the cleanup criteria. **Table 4-4**, reproduced from MARSSIM, illustrates the intended conclusions relative to the data set.

Table 4-4: Initial Survey Unit Evaluation Conclusions

Survey Result	Conclusion
If the difference between maximum survey unit result and the minimum reference area result is less than the cleanup criteria, then:	The survey unit meets release criterion.
If the difference of the survey unit results average and the reference area results average is greater than the cleanup criteria, then:	The survey unit does not meet release criterion.
If the difference between any survey unit result and any reference area result is greater than the cleanup criteria, and the difference of the survey unit average and reference area average is less than cleanup criteria, then:	Conduct the following Wilcoxon Rank Sum (WRS) Test and Elevated Measurement Comparison (EMC) if necessary, to determine if the unit meets release criterion.

Therefore, if all results (Ra-226 + Ra-228, and Th-230 + Th-232, evaluated independently) after background subtraction are below their respective cleanup criterion, then the survey unit satisfies cleanup criteria and no further evaluation is warranted (i.e., WRS test and EMC test are not required).

If the average of the respective results, after background subtraction, is greater than their respective cleanup criterion, then the survey unit will be deemed to have failed and additional investigations and/or remediation should be considered.

If any single measurement exceeds their respective cleanup criterion, then further evaluation via WRS testing and EMC evaluation shall be performed as described in the following sections.

4.4.1 WRS and EMC Testing

The WRS test discussed in this section may also be used to compare each survey unit with the reference area. This test was chosen because contamination is present in the background at the Site.

The comparison of measurements from a reference area to the survey unit is made using the WRS test (MARSSIM [EPA, 2000]). The WRS test is effective when residual radioactivity is uniformly present throughout a survey unit (i.e., the sample distribution is symmetrical). The test is designed to detect whether or not activity exceeds the cleanup criteria.

The Null Hypothesis is assumed to be true unless the statistical test indicates that it should be rejected in favor of the alternative. It is assumed that any difference between the reference area and survey unit concentration distributions is due to a shift in the survey unit concentrations to higher values (i.e. due to the presence of residual radioactivity in addition to background that exceeds cleanup criteria). Survey units may meet the release criteria even though some measurements may be greater than some reference area measurements. Also, survey unit measurements may exceed some reference area measurements by more than the cleanup criteria. The result of the hypothesis test determines whether or not the survey unit as a whole meets the release criterion.

Two underlying assumptions of the WRS test are:

- Samples from the reference area and survey unit are independent, identically distributed random samples; and
- Each measurement is independent of every other measurement, regardless of the set of samples from which it came.

If all of the sample results are less than the cleanup criteria then no WRS statistical evaluation is required.

4.4.1.1 Performing the Wilcoxon Rank Sum Test

The WRS test is applied as outlined in the following six steps by MARSSIM (EPA, 2000):

Step 1

Obtain the adjusted reference area measurements, Z_i, by adding the $DCGL_W$ to each reference area measurement, X_i. $Z_i = X_i$ + cleanup criterion.

Step 2

The *m* adjusted reference sample measurements, Z_I, from the reference area and the *n* sample measurements, Y_I, from the survey unit are pooled and ranked in order of increasing size from 1 to N, where N = *m* + *n*.

Step 3

If several measurements are tied (i.e., have the same value), they are all assigned the average rank of that group of tied measurements.

Step 4

If there are *t* less than (<) the decision level (L_c) values, they are all given the average of the ranks from 1 to *t*. Therefore, they are all assigned the rank $t(t+1)/2t = (t+1)/2$, which is the average of the first *t* integers. If there is more than one detection limit, all observations below the largest detection limit should be treated as < values.

Step 5

Sum the ranks of the adjusted measurements from the reference area, W_r. Note that since the sum of the first N integers is N(N+1)/2, one can equivalently sum the ranks of the measurements from the survey unit, W_s, and compute W_r = N(N+1)/2 - W_s.

Step 6

Compare W_r with the critical value given in MARSSIM Table I.4, Critical Values for the WRS Test, for the appropriate values of *n*, *m*, and ☐. If W_r is greater than the tabulated value, reject the Null Hypothesis that the survey unit exceeds the release criterion. The standard deviation of the sample set is then calculated to establish the relative shift of the test. The relative shift is used to investigate whether or not the survey unit has the proper number of samples.

4.4.1.2 Elevated Measurement Comparison

Both the measurements at discrete locations and the scans may be used to identify elevated areas within a survey unit. Analytical results of soil samples may be used to complete the elevated measurement comparison. If residual radioactivity is found in a localized area of elevated activity—in addition to the residual radioactivity distributed relatively uniformly across the survey unit–the Unity Rule discussed above shall be used to ensure that the release criterion has been met as follows:

$$\frac{\delta}{DCGL} + \sum_{x+1}^{n} \frac{(\delta_{EMC} - \delta)}{DCGL_{EMC}} \leq 1 \qquad (5)$$

where:

δ = the average concentration of Ra-226+Ra-228, or Th-230+Th-232 over the entire survey unit,

δ_{EMC} = the average concentration of Ra-226+Ra-228, or Th-230+Th-232 over the elevated area x within the survey unit,

DCGL = appropriate Ra-226+Ra-228, or Th-230+Th-232 cleanup criterion value,

$DCGL_{EMC}$ = (area factor for elevated area x) X (cleanup criterion value),

x = refers to one of the elevated areas within the survey unit, and

n = the total number of elevated areas within the survey unit.

If there is more than one elevated area, a separate term shall be included for each area. The result of the EMC shall be used as a trigger for further investigation. The investigation may involve taking further measurements to determine that the area and level of the elevated residual radioactivity are such that the resulting dose or risk meets the release criterion. The investigation shall provide adequate assurance, using the DQO process, that there are no other undiscovered areas of elevated residual radioactivity in the survey unit that might otherwise result in an exceedance of the release criterion. In some cases, this may lead to reclassifying a survey unit; unless the results of the investigation indicate that reclassification is not necessary.

4.5 Anticipated Breakdown of FSS Activities

The entirety of Parcel A will be subject to a Class 2 Survey. Parcel A is approximately 28,000 m^2 in area; therefore, three (3) Class 2 survey units are planned, each with a nominal size of approximately 9,500 m^2. Each survey unit will be subject to a 100 percent GWS of all accessible areas. Each survey unit will require a minimum of 10 systematic samples, collected from a triangular systematic grid established from a random staring point. All systematic samples will be collected from the surface. Additionally, Bias samples may be collected from areas corresponding to the historic footprint of the Lounge Building, as well as the historic EPA “exempt areas”. Bias sampling may involve subsurface samples collected via geoprobe.

The entirety of Lower Parcel C will be subject to a Class 2 survey. Lower Parcel C is approximately 9,000 m^2 and will be subject to a single FSS as described above. Additional bias locations within Lower Parcel C, which correspond to historic EPA “exempt” areas may be subject subsurface bias sampling as described above.

The areas of concern for Upper Parcel C are limited to the historic footprints of the Dickson Warehouse and the Benbow Building. Each building footprint will represent the extent of an individual Class 2 survey unit which will be implemented as described above. Additionally, surface scanning immediately adjacent to the building footprints will be performed to ensure that recent demolition activities did not spread contamination.

No FSS is recommended or necessary for Parcel B, based on prior FSS within the Parcel and the absence of activity since the FSS was performed.

Table 4-5: Anticipated Site-wide FSS Activity Summary

Location	Total Survey Units	Total Systematic Samples[1]	Possible Bias Locations[1,2]	10% QC Samples[1]	Total Samples[1]
Parcel A	3	30	4	4	38
Parcel B	0	0	0	0	0
Lower C	1	10	2	2	14
Dickson	1	10	1	2	13
Benbow	1	10	1	2	13
Totals:	6	60	8	10	78

[1] Estimated numbers required in accordance with this FSSP, actual numbers may increase or decrease.
[2] Bias locations may increase or decrease based on survey results and stakeholder direction regarding historical exempt areas.

Figure 4-1 provides an example of potential survey units on the site.

Figure 4-3: Idealized Survey Unit Layout Example

5.0 SURVEY INSTRUMENTATION AND MEASUREMENT TECHNIQUES

This section presents a description of radiological field instrumentation and laboratory measurements that will be used during implementation of this FSSP.

5.1 Land Areas Survey Instrumentation

Prior to the initiation of FSS activities, a 2x2 NaI scintillation detector will be used to develop an MDC and investigation level for gamma scanning of soils. The *a priori* Scan-MDC evaluation was presented in **Section 4.3.2**.

5.1.1 Detection Sensitivity Requirements

Field instrument use will be evaluated and controlled to verify that MDCs less than the appropriate cleanup criteria for scanning measurements are routinely achieved. Implementation of these MDC requirements was discussed in **Section 4.3.2**.

5.2 Laboratory Analysis

An independent, off-site, NYS-certified laboratory, will perform radiological analysis of FSS soil samples. The selected radiochemistry laboratory shall be capable of providing the analytical services required to meet the project DQOs.

Table 5-1 contains a list of gamma and x-ray emissions from the site radiological COCs that may used for determining soil activity concentrations.

Table 5-1: Spectroscopic Gamma Energy Lines and Minimum Detectable Concentrations for Site RCOCs

Radiological COC	Direct / Inferred	Inferred Radionuclide	Photon Emission (keV), *primary	Yield (%)	Sample BEGe MDC (pCi/g)(a)
Th-232	Inferred	Pb-212	238.6	43.3	
		Ac-228	*911.2	25.8	0.25
Th-230	Direct	Not Applicable	12.3 (x-ray) *67.6 (x-ray)	7.7 0.38	~20
Ra-226	Direct	Ra-226	*186.2	3.59	0.5 – 2.5
	Inferred	Bi-214	609.3 1120.3 1764.5	46.3 14.9 15.8	0.05
		Pb-214	242.0 295.2 351.9	7.3 18.4 35.6	0.04
Ra-228	Inferred	Ac-228	*911.2	25.8	0.25

(a) The nuclide MDC values stated in the table are from a 1,500 gram sugar background sample in a Marinelli beaker counted for 20 minutes on a 60% detector inside a lead cave. Actual Site MDCs will vary depending upon detector characteristics, count time, geometry, and activity content of samples.

FSS soil samples will be analyzed off-site for the nuclides of concern via gamma spectroscopy. Ra-226 will be analyzed by gamma spectroscopy after progeny ingrowth (Pb-214 or Bi-214) within a sealed counting container.

6.0 QUALITY ASSURANCE PROGRAM

The objective of a QA program is to identify and implement sampling and analytical methodologies that limit the introduction of error into analytical data. In general, field QA/QC shall be in accordance with the PESI Field Sampling Plan (FSP) (PESI, 2014c) for this FSSP. Laboratory QA/QC responsibilities will rest with the NYS certified contract laboratory.

6.1 FSSP Performance Assessment

On-going assessments and surveillances of FSSP implementation will be conducted in accordance with PESI field sampling plan requirements. Corrective actions resulting from observations shall be promptly implemented. Surveillances (work practice observations) will be informal routine occurrences at the Site, and will be performed by a PESI senior field crew member. The surveillance objective is twofold: (1) verify FSSP requirements are being anticipated and implemented correctly, and (2) identify improvements in work practices improving project efficiency. Supervisory project personnel will be responsible for the effectiveness of the surveillance portion of FSSP performance assessment.

6.2 Field Instrumentation

For all counting systems and instruments used as part of analytical analyses, at a minimum, the following QC principles will be applied.

6.2.1 Procedures

Counting systems and instruments will be used in accordance with approved PESI procedures, as detailed in the Site-specific Field Sampling Plan (FSP) (PESI, 2014d).

6.2.2 Source and Instrument Checks

Each day that a portable counting system and instrument are used, the system's response will be checked using an appropriate source before use. Additional response checks may be necessary depending on the counting system used. In addition:

- For field instrumentation, source check acceptance criteria (e.g., $\pm 2\ \sigma$ for direct [integrated] measurements and ±20 percent for rate measurements) will be established prior to beginning the project.
- All source check results will be documented.
- Failed source checks will be repeated. Consecutive failure will result in additional testing of the counting system, in accordance with the applicable procedure, and ultimately removing the counting system from service.
- Survey data acquired prior to an instrument failing a source check will be reviewed and documented by the Data Manager to determine the validity of the data.
- All instrument failures in the field will be followed by a documented investigation of suspect data.

6.2.3 Background Determination

When FSS activities are conducted, the ambient background will be determined and documented at least once daily per instrument, depending on the instrument used and the variability in the background.

6.2.4 Calibration

All counting systems and instruments will be calibrated with a National Institute of Standards and Technology (NIST)-traceable source at intervals not exceeding 12 months, or as recommended by the manufacturer for portable field survey instruments. The source used will be appropriate for the type and the energy of the radiation to be detected. All calibrations will be documented and include the source data.

6.3 Sample Collection

Soil sampling will be performed in accordance with the Site-specific SAP (PESI 2014d).

6.4 Analytical Laboratory Services

Radiological analytical services provided by each laboratory will be provided in accordance with their internal laboratory QAP (LQAP) implemented by documented policies and procedures. The Data Manager shall confirm that the management objectives of the LQAP, policies, and procedures are to produce data that are scientifically valid, defensible, and of known and documented quality. The Data Manager shall be cognizant of the nature and extent of each laboratory's LQAP and establish a notification protocol with the laboratory should the laboratory QC officer identify LQAP deviations adversely affecting results for the Site.

6.4.1 Laboratory Analysis Specifications

For each laboratory analysis requested, the following minimum specifications will be provided to the laboratory on the appropriate CoC record:

- Required analyses and/or analytical methodology,
- Nonstandard results presentation requirements,
- Sample disposition (disposed or archived), and
- Turnaround time required.

6.4.2 Laboratory Quality Assurance/Quality Control

The contract laboratory shall be NYS certified and compliant. Data packages shall indicate the laboratories QA/QC qualifications and/or deficiencies.

7.0 DATA PACKAGES AND DELIVERABLES

Each survey unit will be evaluated in accordance with MARSSIM, and recommendations regarding the release of the survey unit, based upon satisfaction of cleanup criteria, will be made. The entire data set, and all evaluations used to arrive at conclusions and recommendation will be assembled and provided to all stakeholders. Information to be included in the final report(s) includes:

- Summary of FSS parameters (size, location, classification, sample totals)
- Analytical data, including laboratory data packages
- GWS data including plots of sample locations
- Down-hole gamma logging data, if applicable
- Data set statistics
- WRS Test results, if applicable
- EMC Evaluation results, if applicable
- Descriptions of any QA/QC issues encountered, if applicable
- Conclusions and Recommendations related to the release status of the survey unit and/or Parcel and/or Site.

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PESI, 2014a. *Li Tungsten Data Gap Review and Response to DEC/DOH Comments and Recommendations for Parcels A, B, and C, and Captains Cove*, Perma-Fix Environmental Services, Knoxville, TN, April.

PESI, 2014b. *Justification for Class 2 Survey Units on Parcel A and Lower Parcel C at Li Tungsten, Site No. 130046*, Perma-Fix Environmental Services, Knoxville, TN, June.

PESI, 2014c. *Li Tungsten 2014 Quality Assurance Program Plan*, this document is still in development by Perma-Fix Environmental Services, Inc., Knoxville, TN.

PESI, 2014d. *Li Tungsten 2014 Sampling and Analysis Plan*, this document is still in development by Perma-Fix Environmental Services, Inc., Knoxville, TN.

PWG, 2014. *2014 Subsurface Investigation*, a collection of maps and analytical data generated during a 2014 investigation performed between January and February and available online at https://www.dropbox.com/sh/jspccbmhlrmgw2o/ffYEgtKTi4

TDY, 2009 *Post-Remedial Actions at Parcel B and Upper Parcel C, Li Tungsten Superfund Site, Glen Cove, New York*, prepared for TDY Industries, Inc. by Environmental Chemical Corporation, Lakewood, CO. August.

Client Sample ID:	Site Specific	LT-C-013			LT-C-018			LT-C-045			LT-C-048			LT-C-049			LT-C-060			LT-C-064			LT-C-065		
Sample Depth:	Soil Cleanup Objectives	6-8'			8-10'			4-6'			2-4'			2-4'			6-8'			8-10'			0-2'		
Laboratory ID:		160-5231-3			160-5231-5			160-5519-2			160-5692-7			160-5692-9			160-5697-1			160-5766-4			160-5766-1		
Sampling Date:		1/15/2014			1/16/2014			2/6/2014			2/20/2014			2/20/2014			2/24/2014			2/26/2014			2/26/2014		
		Result		Total Uncertainty (2σ+/-)	Result		Total Uncertainty (2σ+/-)	Result		Total Uncertainty (2σ+/-)	Result		Total Uncertainty (2σ+/-)	Result		Total Uncertainty (2σ+/-)	Result		Total Uncertainty (2σ+/-)	Result		Total Uncertainty (2σ+/-)	Result		Total Uncertainty (2σ+/-)
Method A-01-R - Isotopic Thorium (Alpha Spectrometry) - (pCi/g)																									
Thorium-228	-	0.734		0.200	1.26		0.268	0.393		0.148	0.251		0.117	0.467		0.155	0.388		0.149	0.486		0.153	0.464		0.154
Thorium-230	-	0.754		0.200	0.54		0.166	0.402		0.144	0.376		0.141	0.481		0.153	0.273		0.119	0.385		0.133	0.510		0.158
Thorium-232	-	0.810		0.208	0.885		0.218	0.348		0.132	0.207		0.104	0.383		0.136	0.394		0.143	0.395		0.134	0.556		0.164
Thorium-230 + Thorium-232	≤ 5 + Background*	1.564			1.425			0.750			0.583			0.864			0.667			0.780			1.066		
Method A-01-R - Isotopic Uranium (Alpha Spectrometry) - (pCi/g)																									
Uranium-233/234	-	0.555		0.165	0.582		0.172	0.328		0.146	0.230		0.116	0.394		0.133	0.581		0.167	0.317		0.128	0.374		0.135
Uranium-235/236	-	0.0397	U	0.0493	0.0144	U	0.0287	-0.00347	U	0.00695	-0.00289	U	0.00579	-0.00487	U	0.00690	0.0351	U	0.0469	0.0283	U	0.0400	0.0241	U	0.0380
Uranium-238	-	0.656		0.181	0.702		0.189	0.217		0.117	0.193		0.101	0.407		0.136	0.418		0.138	0.275		0.116	0.293		0.116
Method GA-01-R - Radium-226 & Other Gamma Emitters (GS) - (pCi/g)																									
Actinium 228	-	0.711		0.0941	0.648		0.0705	0.52		0.0637	0.332		0.0402	0.548		0.0611	0.355		0.0433	0.539		0.0605	0.559		0.0625
Bismuth-212	-	0.715		0.232	0.708		0.134	0.58		0.119	0.432		0.115	0.617		0.119	0.366		0.0936	0.595		0.116	0.623		0.123
Bismuth-214	-	0.613		0.0787	0.48		0.0539	0.405		0.046	0.324		0.0381	0.440		0.0484	0.269		0.0322	0.370		0.0426	0.446		0.0498
Lead-210	-	0.555		0.339	0.346		0.101	0.419		0.135	0.296		0.110	0.500		0.137	0.284		0.109	0.374		0.108	0.436		0.127
Lead-212	-	0.734		0.0999	0.696		0.0911	0.51		0.0675	0.343		0.0457	0.596		0.0782	0.310		0.0415	0.540		0.0712	0.608		0.0800
Lead-214	-	0.699		0.0823	0.504		0.0549	0.471		0.0525	0.366		0.0409	0.511		0.0560	0.309		0.0358	0.420		0.0467	0.546		0.0603
Potassium-40	-	8.68		0.97	10.7		1.12	8.43		0.895	11.0		1.14	7.41		0.781	12.1		1.26	6.13		0.656	8.88		0.937
Protactinium-231	-	-0.299	U	0.356	-0.24	U	0.135	-0.181	U	0.154	-0.111	U	0.111	0.0651	U	0.0931	-0.101	U	0.103	-0.206	U	0.133	-0.226	U	0.141
Protactinium-234m	-	0.908	U	1.35	0.939	U	0.651	0.938		0.793	0.620	U	0.666	1.23		0.558	1.24		0.721	0.579	U	0.615	1.67		0.910
Thallium-208	-	0.231		0.032	0.215		0.0246	0.173		0.0214	0.118		0.0147	0.179		0.0207	0.108		0.0136	0.163		0.0193	0.184		0.0214
Thorium-234	-	0.834		0.374	0.495		0.132	0.496		0.146	0.356		0.113	0.587		0.145	0.356		0.123	0.499		0.130	0.604		0.135
Uranium-235	-	0.0468	U	0.0645	0.0395		0.0211	0.0321	U	0.0284	0.0176	U	0.0195	0.0650		0.0286	0.0542		0.0233	0.0554		0.0275	0.0554		0.0260
Uranium-238	-	0.834		0.374	0.495		0.132	0.496		0.146	0.356		0.113	0.587		0.145	0.356		0.123	0.499		0.130	0.604		0.135
Radium-226	-	1.31		0.409	1.17		0.251	0.99		0.226	0.922		0.207	1.06		0.218	0.701		0.172	0.847		0.198	1.11		0.251
Radium-228	-	0.711		0.0941	0.648		0.0705	0.52		0.0637	0.332		0.0402	0.548		0.0611	0.355		0.0433	0.539		0.0605	0.559		0.0625
Radium-226 + Radium-228	≤ 5 + Background*	2.021			1.818			1.51			1.254			1.608			1.056			1.386			1.669		

Client Sample ID:	Site Specific	LT-C-066			LT-C-067			LT-X-002			LT-G-019			LT-G-026			LT-G-027			LT-G-028			LT-G-029		
Sample Depth:	Soil Cleanup Objectives	0-2'			10-12'			6-8'			8-10'			4-6'			8-10'			8-10'			2-4'		
Laboratory ID:	Restricted-Residential	160-5766-2			160-5766-3			160-5231-2			160-5481-1			160-5703-3			160-5703-4			160-5697-2			160-5365-1		
Sampling Date:	Use	2/26/2014			2/26/2014			1/15/2014			2/6/2014			2/21/2014			2/21/2014			2/24/2014			1/28/2014		
		Result		Total Uncertainty (2σ+/-)	Result		Total Uncertainty (2σ+/-)	Result		Total Uncertainty (2σ+/-)	Result		Total Uncertainty (2σ+/-)	Result		Total Uncertainty (2σ+/-)	Result		Total Uncertainty (2σ+/-)	Result		Total Uncertainty (2σ+/-)	Result		Total Uncertainty (2σ+/-)
Method A-01-R - Isotopic Thorium (Alpha Spectrometry) - (pCi/g)																									
Thorium-228	-	0.484		0.164	0.499		0.161	0.644		0.177	0.352		0.14	0.481		0.161	0.335		0.133	1.01		0.250	0.844		0.213
Thorium-230	-	0.660		0.184	0.290		0.119	0.671		0.179	0.268		0.122	0.408		0.146	0.257		0.113	0.953		0.238	0.882		0.218
Thorium-232	-	0.678		0.187	0.411		0.142	0.7		0.183	0.205		0.101	0.348		0.133	0.481		0.155	0.805		0.217	0.852		0.214
Thorium-230 + Thorium-232	≤ 5 + Background*	1.338			0.701			1.371			0.473			0.756			0.738			1.758			1.734		
Method A-01-R - Isotopic Uranium (Alpha Spectrometry) - (pCi/g)																									
Uranium-233/234	-	0.385		0.135	0.190		0.0978	0.612		0.177	0.27		0.112	0.193		0.103	0.644		0.179	0.776		0.195	0.561		0.166
Uranium-235/236	-	0.0346	U	0.0463	0.0333	U	0.0482	0.00905	U	0.03	-0.00251	U	0.00503	0.0384	U	0.0556	0.0220	U	0.0390	0.0398		0.0460	0.0225	U	0.0399
Uranium-238	-	0.447		0.144	0.105		0.0701	0.544		0.166	0.2		0.0953	0.258		0.118	0.635		0.175	0.720		0.187	0.516		0.159
Method GA-01-R - Radium-226 & Other Gamma Emitters (GS) - (pCi/g)																									
Actinium 228	-	0.766		0.0837	0.470		0.0543	0.49		0.0556	0.349		0.0431	0.483		0.0571	0.623		0.0692	1.39		0.151	1.18		0.127
Bismuth-212	-	0.809		0.123	0.533		0.0960	0.535		0.108	0.424		0.0976	0.521		0.0903	0.795		0.141	1.51		0.273	1.17		0.203
Bismuth-214	-	0.586		0.0654	0.222		0.0274	0.397		0.045	0.294		0.034	0.382		0.0429	0.601		0.0667	1.04		0.114	0.832		0.0878
Lead-210	-	0.865		0.191	0.169		0.104	0.499		0.135	0.242		0.0896	0.427		0.122	0.559		0.171	1.04		0.293	0.891		0.194
Lead-212	-	0.839		0.110	0.453		0.0600	0.495		0.0652	0.353		0.0466	0.500		0.0658	0.625		0.0825	1.41		0.156	1.26		0.192
Lead-214	-	0.660		0.0722	0.247		0.0293	0.446		0.0492	0.325		0.0365	0.415		0.0456	0.661		0.0722	1.16		0.119	0.93		0.106
Potassium-40	-	8.92		0.941	5.42		0.578	8.8		0.922	10		1.04	6.74		0.712	10.4		1.09	20.7		2.07	20.4		2
Protactinium-231	-	0.0985	U	0.115	-0.176	U	0.116	-0.148	U	0.117	-0.184	U	0.106	-0.124	U	0.116	-0.173	U	0.155	-0.521	U	0.333	-0.398	U	0.24
Protactinium-234m	-	1.65		0.990	0.592	U	0.456	0.17	U	0.546	0.626	U	0.521	0.611	U	0.524	1.47		0.969	3.24		2.18	2.58		1.29
Thallium-208	-	0.262		0.0298	0.158		0.0184	0.162		0.0191	0.102		0.0122	0.151		0.0178	0.212		0.0249	0.476		0.0540	0.393		0.0428
Thorium-234	-	0.765		0.165	0.307		0.115	0.445		0.137	0.347		0.108	0.453		0.123	0.816		0.184	1.48		0.346	1.06		0.24
Uranium-235	-	0.0539		0.0369	0.0188	U	0.0270	0.0333		0.0239	0.0433		0.0213	0.0327		0.0176	0.0611		0.0270	0.109		0.0543	0.0953		0.0426
Uranium-238	-	0.765		0.165	0.307		0.115	0.445		0.137	0.347		0.108	0.453		0.123	0.816		0.163	1.48		0.346	1.06		0.24
Radium-226	-	1.46		0.308	0.516		0.140	0.972		0.217	0.749		0.168	0.821		0.182	1.79		0.370	2.61		0.480	2.44		0.559
Radium-228	-	0.766		0.0837	0.470		0.0543	0.49		0.0556	0.349		0.0431	0.483		0.0571	0.623		0.0692	1.39		0.151	1.18		0.127

Radium-226 + Radium-228	≤ 5 + Background*	2.226		0.986		1.462		1.098		1.304		2.413		4		3.62	

Notes:

(1)USEPA Site Specific Soil Cleanup Objectives

* background is approximately 1 pCi/g for each isotope

U - Result is less than the sample detection limit.

Highlighted text denotes concentrations exceeding Site Specific SCO

Client Sample ID:	Site Specific	LT-G-029		LT-G-029		LT-R-001		LT-R-001		LT-R-002		LT-R-002		LT-R-003		LT-R-003	
Sample Depth:	Soil Cleanup Objectives	4-6'		4-6'		0-5'		5-10'		0-5'		5-10'		0-5'		5-10'	
Laboratory ID:		160-5697-3		160-5697-3		160-5405-1		160-5405-2		160-5405-1		160-5405-2		160-5606-5		160-5405-3	
Sampling Date:		2/24/2014		2/24/2014		1/31/2014		1/31/2014		1/31/2014		1/31/2014		2/14/2014		1/31/2014	
		Result	Total Uncertainty (2σ+/-)	Result	Total Uncertainty (2σ+/-)	Result	Total Uncertainty (2σ+/-)	Result	Total Uncertainty (2σ+/-)	Result	Total Uncertainty (2σ+/-)	Result	Total Uncertainty (2σ+/-)	Result	Total Uncertainty (2σ+/-)	Result	Total Uncertainty (2σ+/-)
Method A-01-R - Isotopic Thorium (Alpha Spectrometry) - (pCi/g)																	
Thorium-228	-	0.705	0.204	0.705	0.204	0.545	0.161	0.626	0.181	0.415	0.14	0.475	0.155	0.387	0.142	0.486	0.156
Thorium-230	-	0.810	0.214	0.810	0.214	0.584	0.165	0.663	0.184	0.485	0.148	0.856	0.211	0.613	0.176	0.777	0.199
Thorium-232	-	0.763	0.206	0.763	0.206	0.442	0.141	0.766	0.2	0.375	0.127	0.489	0.155	0.580	0.170	0.322	0.127
Thorium-230 + Thorium-232	≤ 5 + Background*	1.573		1.573		1.026		1.429		0.86		1.345		1.193		1.099	
Method A-01-R - Isotopic Uranium (Alpha Spectrometry) - (pCi/g)																	
Uranium-233/234	-	0.407	0.134	0.407	0.134	0.586	0.174	0.59	0.169	0.362	0.132	0.411	0.141	0.361	0.134	0.39	0.142
Uranium-235/236	-	-0.00470 U	0.00665	-0.00470 U	0.00665	-0.000918 U	0.0454	0.067	0.0601	0.00851 U	0.0282	0.0227 U	0.0402	0.0273 U	0.0387	0.0183 U	0.0429
Uranium-238	-	0.507	0.150	0.507	0.150	0.467	0.156	0.684	0.183	0.451	0.147	0.399	0.139	0.375	0.134	0.276	0.118
Method GA-01-R - Radium-226 & Other Gamma Emitters (GS) - (pCi/g)																	
Actinium 228	-	0.918	0.102	0.918	0.102	0.832	0.0906	0.991	0.111	0.605	0.0702	0.599	0.0669	0.531	0.0589	0.511	0.0566
Bismuth-212	-	1.01	0.182	1.01	0.182	0.935	0.146	0.956	0.16	0.624	0.111	0.712	0.132	0.583	0.106	0.514	0.0752
Bismuth-214	-	0.737	0.0807	0.737	0.0807	0.716	0.0781	0.76	0.0844	0.35	0.0404	0.356	0.0409	0.395	0.0444	0.303	0.0352
Lead-210	-	0.857	0.191	0.857	0.191	0.759	0.187	0.937	0.218	0.341	0.108	0.417	0.13	0.471	0.125	0.338	0.0948
Lead-212	-	0.927	0.121	0.927	0.121	0.892	0.117	0.945	0.124	0.611	0.0802	0.622	0.0819	0.565	0.0742	0.535	0.0702
Lead-214	-	0.847	0.0908	0.847	0.0908	0.787	0.0845	0.858	0.0933	0.386	0.0431	0.41	0.0457	0.437	0.0483	0.343	0.0382
Potassium-40	-	13.1	1.37	13.1	1.37	10.4	1.09	18	1.87	8.63	0.906	6.73	0.719	8.28	0.868	7.8	0.818
Protactinium-231	-	-0.239 U	0.170	-0.239 U	0.170	-0.351 U	0.166	-0.264 U	0.182	-0.289 U	0.136	-0.221 U	0.152	-0.253 U	0.120	0.25	0.0667
Protactinum-234m	-	1.21 U	0.781	1.21 U	0.781	1.05 U	0.739	2.59	1.18	1.08	0.638	0.975 U	0.745	0.761 U	0.696	0.714	0.423
Thallium-208	-	0.296	0.0333	0.296	0.0333	0.268	0.0306	0.316	0.0355	0.201	0.0231	0.208	0.025	0.167	0.0191	0.163	0.0186
Thorium-234	-	0.959	0.206	0.959	0.206	0.914	0.185	0.888	0.208	0.525	0.128	0.503	0.164	0.519	0.130	0.435	0.12
Uranium-235	-	0.0595	0.0281	0.0595	0.0281	0.0628	0.0288	0.0883	0.0321	0.0461	0.024	0.0564	0.0295	0.0369	0.0266	0.0276 U	0.0177
Uranium-238	-	0.959	0.206	0.959	0.206	0.914	0.185	0.888	0.208	0.525	0.128	0.503	0.164	0.519	0.130	0.435	0.12
Radium-226	-	1.94	0.394	1.94	0.394	1.59	0.32	1.87	0.383	1.13	0.232	1.03	0.238	0.843	0.181	0.868	0.198
Radium-228	-	0.918	0.102	0.918	0.102	0.832	0.0906	0.991	0.111	0.605	0.0702	0.599	0.0669	0.531	0.0589	0.511	0.0566
Radium-226 + Radium-228	≤ 5 + Background*	2.858		2.858		2.422		2.861		1.735		1.629		1.374		1.452	

Client Sample ID:	Site Specific	LT-XC-020		LT-XC-020		LT-XC-021		LT-XC-023									
Sample Depth:	Soil Cleanup Objectives	6-8'		6-8'		4-6'		8-10'									
Laboratory ID:	Restricted-Residential	160-5692-1		160-5692-1		160-5651-1		160-5651-2									
Sampling Date:	Use	2/20/2014		2/20/2014		2/18/2014		2/19/2014									
		Result	Total Uncertainty (2σ+/-)	Result	Total Uncertainty (2σ+/-)	Result	Total Uncertainty (2σ+/-)	Result	Total Uncertainty (2σ+/-)								
Method A-01-R - Isotopic Thorium (Alpha Spectrometry) - (pCi/g)																	
Thorium-228	-	0.414	0.149	0.414	0.149	0.258	0.122	0.588	0.179								
Thorium-230	-	0.447	0.151	0.447	0.151	0.270	0.122	0.449	0.154								
Thorium-232	-	0.349	0.132	0.349	0.132	0.200	0.103	0.319	0.127								
Thorium-230 + Thorium-232	≤ 5 + Background*	0.796		0.796		0.470		0.768									
Method A-01-R - Isotopic Uranium (Alpha Spectrometry) - (pCi/g)																	
Uranium-233/234	-	0.692	0.237	0.692	0.237	0.171	0.0966	0.438	0.188								
Uranium-235/236	-	0.0852 U	0.0951	0.0852 U	0.0951	-0.00267 U	0.00535	0.0140 U	0.0464								
Uranium-238	-	0.416	0.185	0.416	0.185	0.188	0.0959	0.507	0.199								
Method GA-01-R - Radium-226 & Other Gamma Emitters (GS) - (pCi/g)																	
Actinium 228	-	0.557	0.0615	0.557	0.0615	0.171	0.0232	0.457	0.0518								
Bismuth-212	-	0.648	0.119	0.648	0.119	0.246	0.0715	0.503	0.0934								
Bismuth-214	-	0.379	0.0426	0.379	0.0426	0.136	0.0184	0.272	0.0316								
Lead-210	-	0.434	0.116	0.434	0.116	0.105	0.0644	0.307	0.108								
Lead-212	-	0.595	0.0780	0.595	0.0780	0.178	0.0242	0.487	0.0644								
Lead-214	-	0.412	0.0455	0.412	0.0455	0.152	0.0191	0.318	0.0365								
Potassium-40	-	11.5	1.20	11.5	1.20	6.99	0.738	5.09	0.549								
Protactinium-231	-	-0.260 U	0.1270	-0.260 U	0.1270	-0.0749 U	0.0800	-0.193 U	0.127								
Protactinium-234m	-	1.69	0.717	1.69	0.717	0.351 U	0.461	0.526 U	0.571								
Thallium-208	-	0.174	0.02060	0.174	0.02060	0.0564	0.00800	0.155	0.0184								

Thorium-234	-	0.391	0.0692	0.391	0.0692	0.140	0.0409	0.443	0.124								
Uranium-235	-	0.0486	0.0281	0.0486	0.0281	0.00551 U	0.00940	0.0137 U	0.0188								
Uranium-238	-	0.391	0.0692	0.391	0.0692	0.140	0.0409	0.443	0.124								
Radium-226	-	0.895	0.208	0.895	0.208	0.448	0.117	0.855	0.190								
Radium-228	-	0.557	0.0615	0.557	0.0615	0.171	0.0232	0.457	0.0518								
Radium-226 + Radium-228	≤ 5 + Background*	1.452		1.452		0.619		1.312									

Notes:

(1)USEPA Site Specific Soil Cleanup Objectives

* background is approximately 1 pCi/g for each isotope

U - Result is less than the sample detection limit.

Highlighted text denotes concentrations exceeding Site Specific SCO